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ABSTRACT: The contribution of parental smoking to wheezing in children was studied in a subset of all British births between April 5 and 11, 1970 (N=9,670). Children of smoking mothers had an 18.0 per cent cumulative incidence of post-infancy wheezing through 10 years of age, compared with 16.2 per cent among children of nonsmoking mothers (risk ratio 1.11, 95% CI: 1.02, 1.21). This difference was confined to wheezing attributed to wheezy bronchitis, of which children of smokers had 7.4 per cent, and those of nonsmokers had 5.2 per cent (risk ratio 1.44, 95% CI: 1.24, 1.68). The incidence of wheezy bronchitis increased as mothers smoked more cigarettes. After multiple logistic regression analysis was used to control for paternal smoking, social status, sex, family allergy, crowding, breast-feeding, gas cooking and heating, and bedroom dampness, the association of maternal smoking with childhood wheezy bronchitis persisted. Some of this effect was explained by maternal respiratory symptoms and maternal depression, but not by neonatal problems, the child's allergic symptoms, or paternal respiratory symptoms. There was a 14 per cent increase in childhood wheezy bronchitis when mothers smoked over four cigarettes per day, and a 49 per cent increase when mothers smoked over 14 cigarettes daily.

Parental Smoking and Post-Infancy Wheezing in Children: A Prospective Cohort Study

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Abstract: The contribution of parental smoking to wheezing in children was studied in a subset of all British births between April 5 and 11, 1970 (N = 9,670). Children of smoking mothers had an 18.0 per cent cumulative incidence of post-infancy wheezing through 10 years of age, compared with 16.2 per cent among children of nonsmoking mothers (risk ratio 1.11, 95% CI: 1.02, 1.21). This difference was confined to wheezing attributed to wheezy bronchitis, of which children of smokers had 7.4 per cent, and those of nonsmokers had 5.2 per cent (risk ratio 1.44, 95% CI: 1.24, 1.68). The incidence of wheezy bronchitis increased as mothers smoked more cigarettes. After multiple logistic regression analysis was used to control for paternal smoking, social status, sex, family allergy, crowding, breast-feeding, gas cooking and heating, and bedroom dampness, the association of maternal smoking with childhood wheezy bronchitis persisted. Some of this effect was explained by maternal respiratory symptoms and maternal depression, but not by neonatal problems, the child's allergic symptoms, or paternal respiratory symptoms. There was a 14 per cent increase in childhood wheezy bronchitis when mothers smoked over four cigarettes per day, and a 49 per cent increase when mothers smoked over 14 cigarettes daily. (*Am J Public Health* 1989; 79:168–171.)

Introduction

Children are passive victims of the effects of tobacco smoke from their surrounding environment, resulting in multiple adverse health outcomes.[1–3] Passive smoking has been associated with respiratory infections and symptoms in infants and young children.[4–9] Some studies have suggested an association between parental smoking and wheezing or other respiratory symptoms of older children,[10–14] but other investigations have disputed this relationship.[15–17] A dose effect has been reported,[4,6,12,18–21] although this has been inconsistent and often crudely measured.[8] Parental smoking has also been associated with decreased pulmonary function and lung growth in children.[11,14,19,22–25]

The mechanism of effect of passive smoking on childhood reactive airway disease is not clear. Sidestream tobacco smoke may be directly toxic to the lungs of children. Alternatively, or additionally, the respiratory effects of passive smoking may be mediated by other factors to which children of smokers may be exposed, such as infection,[10,18,26,27] allergy,[15,28] stress,[29] or neonatal respiratory problems.[23]

In order to address some of these unresolved issues, we studied the relationship of cigarette smoking by either or both parents with report of post-infancy wheezing in a large, representative British national cohort.

Methods

The Child Health and Education Study began as a national survey of all births in Great Britain during the week of April 5–11, 1970.[30] Information was collected by midwives during the first postpartum week. At 5 years of age, the cohort was reevaluated by trained health visitors via maternal interviews. Additional parental interviews, medical examinations, and educational evaluations were carried out at age 10.

Maternal smoking behavior was surveyed at each interview, including the duration of smoking from pregnancy through age 10 of the child and the usual dose of cigarettes per day during each period. We asked about the use of cigarettes, pipes, or cigars by the father. The amount smoked by the mother was categorized on the birth questionnaire as 0, 1–4, 5–14, 15–24, and 25 or more cigarettes per day. These categories were applied to doses reported at children's ages 5 and 10, from the continuous measures of amount smoked (there was considerable preference for multiples of five in reporting of dose). In trend analyses, means of each of the first three smoking categories were used: 2.5, 9.5, and 19.5; 29.5 cigarettes per day was used for the highest smoking category.

Outcome data were obtained from maternal interviews when the children were 10 years old. At that time, parents were asked: "Has the child *ever* had one or more attacks or bouts in which there was wheezing or whistling in the chest?" If the reply was positive, they were asked: "What were these thought to be due to?" (. . . asthma, wheezy bronchitis, or other cause, with multiple responses permitted); parents were then asked at what ages the wheezing occurred. Wheezy bronchitis is a common diagnosis in Great Britain, although its clinical distinction from asthma is not clear.

Other variables were selected for study after review of published investigations or parental smoking and other factors related to childhood respiratory symptoms and disease. These included sex of the child, social status of the family (represented by a standardized variable derived from factor analysis of social items when the cohort was 5 years old), crowding in the home (total persons/total rooms), number of siblings (total, older and younger), dampness in the child's bedroom, whether gas was used for cooking and/or heating, child's own smoking at age 10, whether the child was breast fed at least one month, history of allergy in the child or family, neonatal respiratory problems, symptoms of chronic cough or phlegm for over three months in each parent, and a measure of maternal depression (derived from a 24-item Malaise Inventory[31]). Family allergic history was determined at the time the child was age 5 by a report of asthma, eczema, or hay fever in either natural parent. A positive allergic history in the child was defined as a report of eczema or hay

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fever before 5 years of age. Neonatal respiratory problems were defined by a history of any breathing difficulties during the first week of life.

Chi-square, multiple logistic regression, and factor analyses were done using SAS software.[32,33] Confidence intervals on risk ratios[34] and on odds ratios determined from multiple logistic regression[35] were calculated using published methods. Attributable risk calculations were done using methods described by Lilienfeld.[36]

Results

We studied prospectively 11,776 children born between April 5–11, 1970 and their families, obtaining data at birth, and at ages 5 and 10 years. Of this population, 9,953 (84.5 per cent) were singleton births, living throughout with their natural mothers, whose primary language was English, and who were ethnic Europeans. In 836 of these households (8.4 per cent), there was no father figure. There were 5,113 boys (51.4 per cent).

The 9,670 children whose mothers had known smoking information comprise the cohort for the remaining analyses. Of these mothers, 4,855 (50.2 per cent) smoked cigarettes at some time between their pregnancy and the child's age 10. Cigarette smoking was reported at some time by 5,128 fathers in homes with a father figure (56.2 per cent). In addition, 866 (9.5 per cent) of fathers smoked pipes or cigars only.

There were 1,774 children (17.8 per cent) who were reported to have wheezed by 10 years of age. Of these, 112 reported wheezing only before one yer of age; the remaining 1,662 were classified by their parents as having asthma, wheezy bronchitis, or other reasons for wheezing. The relationship of post-infancy wheezing to maternal smoking at any time between pregnancy and child's age 10 (dichotomized) is presented in Table 1. Smoking was associated with post-infancy wheezing in the entire group of children (risk ratio 1.11, 95 per cent CI = 1.02, 1.21). This smoking relationship was limited to the subgroup stated to have had wheezy bronchitis (risk ratio 1.44, 95 per cent CI = 1.24, 1.68). Subsequent analyses relate only to this outcome.

Unadjusted relationships of maternal and paternal smoking with child's wheezy bronchitis are shown in Table 2. The effect of maternal smoking was stronger when fathers also smoked, but these mothers also smoked more cigarettes per day: during pregnancy, 12.5 per cent smoked over 14 cigarettes per day, compared with 4.5 per cent when fathers were nonsmokers. In the homes with no father figure, there was a higher cumulative incidence of wheezy bronchitis.

Wheezy bronchitis was reported to have started before age 5 in 72 per cent of affected children (compared with 65 per cent of those with asthma). The amounts that the mother smoked at child's birth and age 5 years were equally strongly related to the risk of wheezy bronchitis. Thus, the mean dose of cigarettes per day between the reported amounts at birth and 5 years was used in subsequent dose analyses. The cumulative incidence of wheezy bronchitis by amount smoked by the mother is presented in Table 3. The incidence of wheezy bronchitis increased progressively from 5.2 per cent in nonsmokers to 8.9 per cent among children whose mothers smoked over 24 cigarettes per day, but this dose-effect trend among smokers was not statistically significant.

Wheezy bronchitis was inconsistently related to the duration and period of maternal smoking (Table 4). Those mothers who smoked throughout the study period (from pregnancy through child's age 10) also smoked more cigarettes; their children had a risk ratio of 1.52 (95 per cent CI = 1.27, 1.82) for wheezy bronchitis compared with nonsmokers. The category of mothers who only smoked in both postnatal periods was most strongly related to childhood wheezy bronchitis, although only 12 cases were exposed in this group.

Multiple logistic regression was used to estimate the effects of several factors of post-infancy wheezy bronchitis contrasted with no history of wheezing. The final model included maternal smoking between child's birth and age 5 years with four dose levels; paternal smoking in three categories: cigarette smoking, pipe or cigar smoking only, or father absent from the home; social status, sex of the child, family history of allergy, crowding, breast-feeding, gas cooking or heating, and bedroom dampness. The included social status items after factor analysis were: father's highest educational qualification, father's occupational social class, mother's highest educational qualification, economic level of the neighborhood, telephone in the home, and ownership/rental of home. Highly correlated, redundant variables (e.g., number of siblings) were substituted by more specific mea-

TABLE 1—Post-Infancy Wheezing to Age 10 by Maternal Smoking at any Time

Reason for Wheezing	Affected Number	Cumulative Incidence		Risk Ratio (95 CI)
		Smokers	Nonsmokers	
Wheezy bronchitis	625	.074	.052	1.44 (1.24, 1.68)
Asthma	282	.028	.029	.96 (.77, 1.22)
Other reason	632	.064	.067	.96 (.83, 1.11)
Combinations of above	123	.013	.013	1.00 (.71, 1.41)
Total	1662	.180	.162	1.11 (1.02, 1.21)

TABLE 2—Cumulative Incidence of Wheezy Bronchitis in Ages 1–10 by Parental Smoking

Maternal Smoking	Paternal Smoking (Number with wheezy bronchitis)				N
	No	Cigarettes	Pipe/ Cigar	Father Absent	
No	.051 (110)	.050 (93)	.052 (27)	.066 (18)	4815
Yes	.066 (59)	.076 (238)	.064 (20)	.083 (44)	4855
Total	.055 (169)	.067 (331)	.056 (47)	.077 (62)	9670
Risk Ratio of Maternal effect (.95 CI)	1.29 (.95, 1.75)	1.52 (1.20, 1.92)	1.23 (.70, 2.15)	1.26 (.74, 2.14)	

TABLE 3—Cumulative Incidence Rate of Wheezy Bronchitis at Ages 1–10 by Maternal Smoking Dose

	Average cigarettes per day at birth and 5 years				
	None	1–4	5–14	15–24	>24
Cumulative Incidence Wheezy Bronchitis	.052	.066	.075	.081	.089
Number Children*	4815	925	2450	991	169
Rate Difference	—	.013	.023	.029	.037

Chi-square (trend) = 1.876, p = 0.17.
*240 smoking mothers did not smoke at child's birth or age 5 years; 80 had incomplete dose reporting.

TABLE 4—Incidence of Wheezy Bronchitis (WB) by Period of Maternal Smoking

Pregnancy	Child's Age 0–5	Child's Age 5–10	N	# WB	Cumulative Incidence WB	RR WB	95% CI
n	n	n	4815	250	.052	—	
y	y	y	3302	260	.079	1.52	1.27, 1.82
y	y	n	538	35	.065	1.25	0.87, 1.80
y	n	y	307	20	.065	1.25	0.79, 2.00
y	n	n	164	11	.067	1.29	0.70, 2.39
n	y	y	107	12	.112	2.16	1.19, 3.93
n	y	n	197	15	.076	1.46	0.86, 2.50
n	n	y	240	10	.042	0.80	0.43, 1.51

y = Smoked during pregnancy, or at least three years during interval
n = Did not smoke in pregnancy, or less than three years during interval
RR = Risk ratio

sures (e.g., crowding). Variables unrelated to smoking or wheezing were not included.

The interaction between maternal smoking and the following variables were estimated by both bivariate and multivariate analyses: sex, maternal depression, child allergy, parental allergy, neonatal respiratory distress, breast-feeding, gas cooking, gas heating, crowding, social status, or paternal smoking. The effect of maternal smoking on wheezy bronchitis showed little difference among the levels of any of these factors. Thus, the final multiple logistic models excluded interaction terms.

As Table 5 shows, the dose relationship with maternal smoking appeared to plateau at 15–24 cigarettes per day when all potential confounders were controlled. Male sex, low social status, family allergy, and bedroom dampness, when controlled for maternal smoking, were related to wheezy bronchitis.

Several variables were examined as potential mediators of the smoking effects by adding each separately to the full analytic model, including neonatal respiratory problems, child allergy, and parental respiratory symptoms. These mediating effects were strongest among children whose mothers smoked over 24 cigarettes per day: the maternal smoking effect was reduced (from 1.49 to 1.32) when maternal respiratory symptoms were controlled; parental symptoms exerted no such effect, despite the stronger independent contribution of fathers' report of cough or phlegm to the child's symptoms. A smaller reduction in effect (to 1.36) was evident when maternal depression was included in the analysis. An increase in the effect (to 1.61) was seen when child allergy was held constant. Neonatal respiratory problems showed no mediating effect.

If mothers smoking over four cigarettes per day had not smoked, we estimate that 13.8 per cent of the total burden of wheezy bronchitis in this population would not have occurred.

TABLE 5—Child's Wheezy Bronchitis by Age 10 Years and Maternal Smoking: Multiple Logistic Regression

# cig/day* (N)	Odds ratios vs nondiseased children (95% CI) controlled for covariates**
None	1.00
1–4 (925)	1.27 (.95–1.70)
5–14 (2450)	1.43 (1.16–1.78)
15–24 (991)	1.49 (1.13–1.97)
>24 (169)	1.49 (.85–2.63)
*Average of amount between birth and age five	
**Covariates in model, multivariate odds ratio (95% CI):	
Paternal cigarettes	1.05 (.85, 1.29)
Paternal pipe/cigar	1.05 (.75, 1.46)
Father absent	1.08 (.81, 1.43)
Male child	1.39 (1.16, 1.64)
Family allergy	1.48 (1.22, 1.78)
Crowding	0.91 (.71, 1.17)
Bedroom dampness	1.67 (1.31, 2.14)
Not breast fed	1.22 (.97, 1.53)
Gas cooking/heating	1.03 (.86, 1.23)
Social status factor	0.90 (.81, .99)

Discussion

In this large, representative national cohort of British children followed from birth, 18 per cent were reported to wheeze by 10 years of age. A subgroup of these children (those whose symptoms were attributed by their mothers to wheezy bronchitis) were at increased risk of post-infancy wheezing when their mothers were smokers. Paternal smoking did not contribute independently to the risk of wheezy bronchitis, perhaps because young children spent more time with their mothers. Recent changes in parental work and child care patterns may alter these relationships.

Is tobacco smoke directly toxic to children's lungs, or are its effects attributable to other factors? Parents who smoke have more respiratory symptoms themselves and may transmit infections to their children.[10,26,27] Additionally, children may imitate the respiratory symptoms of their parents. We found that report of maternal cough or phlegm resulted in some attenuation of the relationship of maternal smoking with the child's wheezy bronchitis; paternal symptoms showed no such relationship. This finding is consistent with mediation of some of the effect of maternal smoking on the child's wheezing by maternal respiratory symptoms; it also is consistent with maternal smoking jointly causing maternal symptoms and the child's wheezy bronchitis, or with more frequent reports of wheezy bronchitis in children of smoking mothers with respiratory symptoms. A substantial portion of childhood wheezy bronchitis was unexplained by these mediating factors, either due to actual toxicity of sidestream tobacco smoke or unexamined mediating factors.

Passive smoking was related only to wheezy bronchitis and not to reported asthma or wheezing for other reasons. We do not know what clinical characteristics led to the perceived diagnosis of wheezy bronchitis in these children. Several investigators have suggested that asthma and wheezy bronchitis are clinically and pathologically indistinguishable, and that they are both manifestations of reactive airway disease.[37,38] The distinct patterns of association of different categories of wheezing with parental smoking found in this cohort may represent true differences between various forms of wheezing.[39] Alternatively, children exposed to tobacco smoke may have been labeled disproportionately as having wheezy bronchitis by health care providers because of earlier age of onset than expected for asthma, relative absence of other atopic symptoms, or awareness of early published reports of an association between passive smoking and bronchitis in childhood.

Reliance on parent report of smoking and retrospective report of childhood wheezing may add uncertainty to our findings.[8,24] However, the causal relationship between pas-

sive smoking and childhood reactive airway disease is supported here by consistency with previous investigations, temporal coherence of the sequence of exposure and symptoms, a dose-response gradient, and biologic plausibility.[40] Our data do not reveal a specific period of vulnerability to the effects of passive smoking. Further follow-up of this cohort is in progress and may add to our understanding of the effects of passive and active smoking on the natural history of reactive airway disease.

We estimate a 49 per cent increase in the prevalence of childhood wheezy bronchitis by age 10 when mothers smoke more than 14 cigarettes per day, when compared with children of nonsmoking mothers. Perhaps as much as 14 per cent of wheezy bronchitis in this population can be attributed to maternal smoking of over four cigarettes per day. These findings add evidence of the public health hazards of cigarette smoke to those involuntarily exposed.

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